Enhanced Bomb Effects for Obstacle Clearance
(Analysis Task)

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LONG TERM GOALS

The Navy has identified the need for a system capable of simultaneously breaching obstacles and clearing mines, in-stride, from over the horizon, during an amphibious assault. In response to the obstacle-breaching concern, the Enhanced Bomb Effects for Obstacle Clearance program was started. The purpose of the NSWCDD/CSS Bomb Effects program is to study and identify the damage mechanisms of obstacles (on land and in water) subjected to multiple bomb detonations. This acquired knowledge will then provide the acquisition community with the information necessary to utilize the proper technology for development of an obstacle clearance system.

OBJECTIVES

Standard GP bombs represent an existing, rapidly deployable, building block for developing an effective system against obstacles. In order to expand the existing knowledge base on the effectiveness of these weapons against obstacles, an analytical effort was launched to complement the experimental efforts performed by NSWCDD/CSS. The analytical efforts (performed by NSWC Indian Head and Advanced Technology and Research, Corporation) which have supported the Bomb Effects program evolved from the following objectives:

- Develop semi-analytic/empirical models to predict the loading environment generated by multiple bomb blasts.
- Provide data and models so that the fidelity of empirical models can be enhanced, and more accurately represent explosive performance against obstacles in the near shore surf zone environment.
- Analyze and model the performance of simultaneously detonated GP bombs.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **Enhanced Bomb Effects for Obstacle Clearance (Analysis Task)**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center,Indian Head Division,Indian Head,MD,20640**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

- Develop analytic models to predict the dynamic elastic-plastic response of tetrahedron obstacles in terms of deformation and strain in critical elements of the obstacle.
- Identify the kill mechanism and, by analysis and test, quantify the level of strain, which results in total collapse of the obstacle.
- Quantify the lethal radius of Mk 83 general-purpose bombs.
- Develop an analytic model to predict cumulative damage (kill) from sequential detonation of multiple bombs.

Thus, the goal of the analytical Bomb Effects effort is to develop analytic models (explosive output and obstacle response) to predict the lethal (kill) radius of general-purpose bombs. The output of these models will be in a form that can be implemented in a Monte Carlo Obstacle Clearance (OBSCLR) Code to estimate the number of bombs necessary to clear a band of obstacles on the beach or in the surf zone. Such a capability would ultimately be used to plan a tactical concept of operations during an amphibious assault.

APPROACH

Up to the current time, we have relied mainly on data from field tests of full-scale Mk 82 and Mk 83 bombs to estimate the lethal radius against various types of obstacles such as tetrahedrons, hedgehogs, and concrete cubes. We are using this data to serve as bench marks for validation of the analytic and hydrocode models being developed. The models must be accurate but simple to the extent that they can be implemented into complex Monte Carlo obstacle clearance models which account for aircraft delivery accuracy including bomb circular error probability (CEP). Hence analytic models are being developed based on elastic-plastic beam theory including strain rate effects. These analytic models are then compared to more sophisticated analyses using finite-element codes such as DYNA3D and the DYSMAS hydrocode for validation. Initial estimates of shock pressure from bomb detonations in water are based on spherical charges using the well-known explosive similitude equations. The DYSMAS hydrocode is subsequently used to account for the effect of cylindrical charges (vice spherical charges) and to account for fluid-structure interaction.

WORK COMPLETED

Explosive Output Analytical Effort

The explosive output analytical effort examined, evaluated, and characterized the explosive output of large bombs. Understanding such loads is a precursor to the ultimate program goal of understanding, and predicting, the target (or, tetrahedron obstacle) response.

- Developed loading characterizations of single and multiple bomb blasts in air. Specifically, the characterization of pressure and impulse histories, as generated from the detonation of multiple bombs, was completed via analysis of explosive data. The explosive data was obtained from two resources: one, an existing empirical database (including experimental data generated by NSWCDD/ CSS), the other, hydrocode-computed predictions. The derived characterization describes the decay of pressure as a function of time and as a function of distance from the bomb(s); the impulse is characterized via integration of the pressure.

- Developed a semi-analytic/empirical model to predict the explosive output from multiple bombs. The application utilizes the previous developments to predict the loading environment surrounding a near infinite set of bomb configurations. This application quickly produces bomb pressure and impulse signatures, contours, etc., and, thereby, provides an effective and efficient tool for performing bomb configuration parametric studies.
- Analyzed the effects and interaction of the obstacle with the incident explosive blast load (i.e., the “near-target” effects) and compared them with the free-field loads.

Obstacle Response Analytical Effort

The obstacle response analytical effort concentrated on the modeling and characterization of the response of steel tetrahedron obstacles to the explosive loading from Mk 80 series bombs.

- Analytic models were developed which agreed well with the DYNA3D finite element code for given dynamic pressure-time curves.
- We completed DYSMAS hydrocode calculations to predict the obstacle deformation and strain as a function of Mk 83 bomb standoff from the obstacle.

Obstacle Lethality Effort

This effort focused on assessing obstacle lethality.

- DYSMAS and DYNA3D finite-element code analyses were completed to determine the area of critical strain and the subsequent failure mechanism of the tetrahedron obstacle.
- A static test of the tetrahedron weld joint was completed to determine the critical strain to cause failure of the weld.

RESULTS

The analytical efforts resulted in several significant findings summarized as follows:

- Analysis was performed of the effects and interaction of the obstacle with the incident explosive blast load (i.e., the “near-target” effects), and compared with the free-field loads. This analysis was performed computationally, due to the complex nature of such shock-structural interactions. An eulerian hydrocode (DYSMAS) modeled the simplified cross-section of a representative obstacle (namely, the leg of a steel tetrahedron). The near-target analysis of the blast loading revealed amplifications of the incident loads by as much as a factor of ten. Such magnifications are due to the stagnation of the flow field at the face of the structure and to the reflection of the shock off of the target. The insight into these near-target effects will assist in future evaluations of obstacle damage and lethality.
- Based on the experience in the analysis of open frame structures for airblast, it is generally assumed that the principal loading is drag loading from high velocity particles on the structure; namely the dynamic pressure times a drag coefficient C_dq. This assumes diffraction loading from the direct and reflected shock is of short duration and can be neglected. The DYSMAS hydrocode allowed us to compute the shock pulse accounting for surface reflection underwater, and fluid-structure interaction including diffraction of the shock wave around the tetrahedron. The analysis clearly

showed that while dynamic pressure loading constitutes a significant portion of the loading, diffraction loading including local reflected shocks need to be considered.

- The typical, or frequently used, characterization of a bulk explosive pressure signature at some point distant from the charge is that of a single exponential decay with time. The use of such a relation proved to provide less than adequate comparisons to experimental data in FY97. The FY98 effort developed a new relation, which is much better for the range of standoffs of interest to the Bomb Effects program. Specifically, for standoffs less than thirty charge diameters, the following relation provides an improved prediction of the pressure signature:

$$P(t) = PP/2*[e^{-(t-toa)/\theta 1} + e^{-(t-toa)/\theta 2}]$$

Where,

$$PP = aR^{-b}$$
$$\theta 1 = cR^{d}$$
$$\theta 2 = e\ln(R) - f$$

and, $P(t)$ is the pressure signature of interest, PP is the peak pressure of the signature, toa is the time of arrival of the shock front, $\theta 1$, $\theta 2$ are the decay constants, R is the range, or standoff from the explosive to the point of interest, and a,b,c,d,e,f are empirically fitted constants.

- The shock pressure, impulse and energy from underwater explosives are frequently computed using the well-known similitude equations for spherical charges. By modeling the Mk 83 general-purpose bomb as a cylindrical charge (vice spherical), we learned that the cylindrical charge yields somewhat higher pressure than the spherical charge for the standoff ranges of interest.
- It was found that the primary kill mechanism is failure of the weld joints as demonstrated by tests and analysis using the DYNA3D finite-element code and DYSMAS hydrocode (Figure 1).
- Based on comparison with DYSMAS and DYNA3D results, the analytic model developed has sufficient accuracy to estimate the lethal radius of bombs given that we use the weld strength obtained in the tests. One area of concern needing additional study is to determine the strength of the weld as a function of strain rate.
- Given that cumulative damage can be obtained from well-structured field tests exposing the tetrahedron to sequential detonations, the analytic cumulative damage analytic model developed provides the basic physics to develop a correlation algorithm that can be implemented into a Monte Carlo program to assess kill probability.

IMPACT/APPLICATIONS

These findings have significant tactical implications. The capability to calculate pressure, impulse and energy from in-air and/or underwater explosions coupled with the capability to compute the dynamic response of the obstacle will allow computation of lethal radii of general-purpose bombs. This capability will permit analytical estimates of the number of bombs/aircraft sorties to clear obstacles in a given tactical scenario.

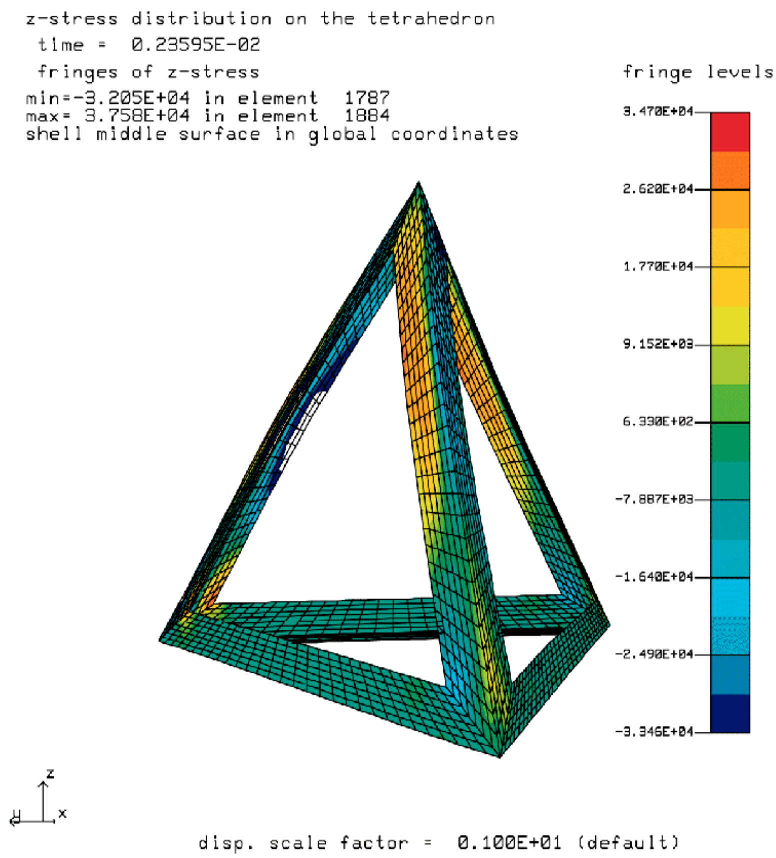

Figure 1. Stress Fringes in Tetrahedron Obstacle

TRANSITIONS

The analytic models will be transitioned to NSWC/CSS and PMS407 to allow the effectiveness of general-purpose bombs in obstacle clearance to be evaluated.

RELATED PROJECTS

This project exploits and builds on test data obtained from ongoing 6.4 and 6.5 mine and obstacle breaching programs; specifically Mk 83 tests from Obstacle Breaching Program, APOBS testing and SABRE testing.

The Standoff Delivery effort is helping define the limits of bomb verticality that are achievable and this will impact some of the planned testing and modeling efforts.

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